Filters for automotive industry

by P.Ganesan, L.Sasikala, S.Sundaresan, K.Gowri, R.Senthilkumar.

Abstract: This paper deals about the automotive filters and points out the most common applications using fibers, textiles and non woven fabrics. The readers will be pleasantly surprised how widely these materials have found their way, in whole or in part within filter configurations, and in such a variety of applications. It also gives information about new type of fabrics and yarn structures, which increase the life and performance of automotive filters. The article also elaborates how Filter performance is evaluated and related developments in this field.

Introduction

The performance of an automobile is bolstered significantly by the presence of high performance filter media in the engine compartment and in various other locations. The purpose of filter is to control contamination, through achieving a balance between the sources of contamination and the ability of a system to tolerate contamination. The ultimate goal is to balance filtration performance with the desired cleanliness level.

The media in a filter is the physical mechanism used for contamination control. Media construction and filter configuration are used to determine the filter's efficiency for particle removal, its contaminant capacity and the pressure drop, or resistance to flow, through the filter. By working with these variables - efficiency, capacity, pressure drop - the filter's performance level can be determined. For effective functioning of automobile engine and to obtain clean cabinet, proper functioning of filter fabrics is very important. Automotive filter business is however mainly concerned with air filters, oil filters, fuel filters and cabin filters

Materials and functions of filters

The filter media ranges from mesh screens to depth style media such as threads or chopped paper to 100% natural cellulose to 100% man-made fibers to almost any conceivable combination in between. Table 1. outlines an overview of filtration applications in the automotive industry. With so many media choices, it becomes a complex aspect to choose a right kind of media for an engine system. While keeping in mind the purpose of filtration, the manufacturer has to make a performance decision regarding the physical size of contamination that can be tolerated by the system.

Typically, if only larger particles are to be removed, a very basic cellulose media is used. As the size of contamination to be removed gets smaller and smaller, the type of media changes from more complex cellulose to blended media where cellulose and man-made fibers are blended together in various configurations. For the removal of extremely small contamination, media typically changes from one dominated by cellulose to one made exclusively from various types of man-made fibers. The logic behind choosing man-made fibres is owing to its level of achievable fineness. Finer the fibre greater will be the particle capturing. Recently nano-fibre materials are becoming popular.

Fig.1 Different types of air filters.

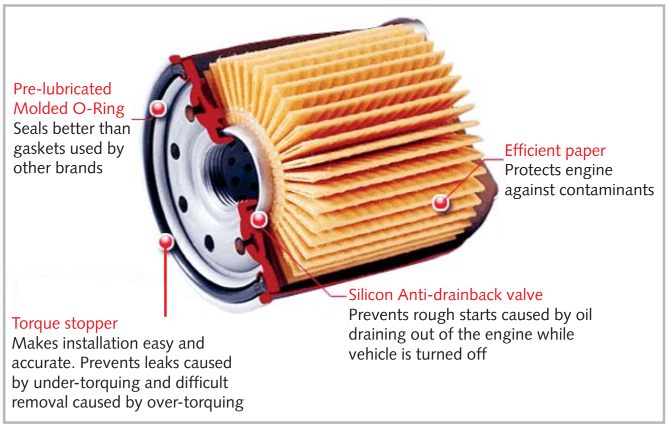
Air filters

Air is vital to vehicles engine. It is mixed with fuel, ignited and with the resulting controlled explosion provides power to vehicle. It takes between 10,000 to 12,000 gallons of air for each gallon of fuel. The only way for air to enter the engine is through the air intake after passing through the air filter (Fig.1), which is essential in removing contaminants such as dirt particles, dust and debris from the air penetrating the engine, which can cause damage to engine cylinders, wall, pistons and piston rings whilst allowing high volume of air to pass through. If the air filter is clogged up, engine performance is reduced, engine power decreases and engine wear is increased.

An established site for the air filter in the engine of an automobile is in the carburetor. The filter stationed here is normally a wet laid nonwoven material. Commonly this medium is a mixture of cellulose fibers that are derived from the wood pulp, with small amount of synthetic fiber. The fiber scaffold is imparted with stiffness by a resin binder. Air filter can consists of 1-20 layers, which are normally pleated to increase the surface area. In multilayers, the densest layer resides on the exit plane and a less dense layer covers the entry. This arrangement confers a gradient density capability where by gradually smaller particles are held in the deeper layers of the filter. Another version of this medium is available in which the fibres are more intermingled.

Table-1: Automotive filtration applications and filter media

Application	Type of filter media
Carburetor air filters	Mainly nonwoven (wet, dry, needled or spun bonded)
Engine oil filters	Resin impregnated wet laid nonwoven (paper)
Fuel tank filters	Activated carbon
Cabin interior filters	Electrostatically charged fibre media, nonwovens, activated carbon, specialty paper.
Diesel/soot filters	Ceramic materials
ABS wheel/ brake filters	Metal or fibre woven screens
Power steering filters	Mainly screen fabrics
Transmission filters	Woven fabrics or needle felts
Wiper washer screen filters	Woven fabrics
Air conditioning recirculation filters	Nonwoven / activated carbon
Crank case breathe filters	Nonwovens



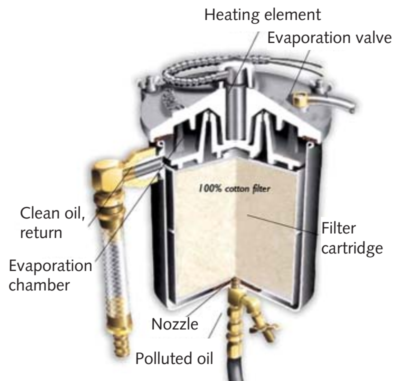


Fig.2 Oil filters.

Apart from these two techniques, it is also possible to manufacture filter by dry-laying. Generally, this kind of filter consists of a fleecy top web, an open structured inner layer, and a dense lower layer. This type of filter is composed of a blend of synthetic and cellulosic fibres. Inside the filter the cellulosic fibres normally furnish the lower section, which is particularly dense. At present, most development on the carburetor air filter is being conducted in Japan, where Toyota have designed a more expensive media that is made from needled felt and spun bonded material

Filtration through an engine mounted air filter is accomplished through four mechanisms. The first mechanism is where foreign particles adhere to the media via the impact impingement mechanism. Here, dirt strikes the filter and attaches itself permanently. In the second mechanism, dirt can collect as cluster aggregates, which are collection of particles, created by the triboelectric nature of fibres or the electrostatic charge that is generated during fluid flow.

Thirdly, dirt can be trapped between the pores of the filter media, particularly when they become clogged and reduced in size. The last opportunity for a filter to capture dust arises from the interaction between fluid flow and pressure drop. When all these mechanisms are employed, the total void volume of an air filter can be filled to 90% by the end of its useful life.

Oil filters

Dirt is one of the major causes of engine wear. Dirt particles are extremely abrasive and these particles are carried by the oil into the precision clearances between bearings and other moving parts. Once they work in between in these parts, they grind and groove surfaces, altering clearances, and generating more debris that is abrasive. As this wear cycle continues precision components become progressively sloppy and fatigued, until they fail altogether.

In addition to physically assaulting engine components, dirt and other contaminants work to degrade the oil that provides vital engine lubrication. Dirty carbon particles generated during combustion can be forced past piston rings and into the oil. These particles by their very nature act like tiny sponges, absorbing critical additives, thus shortening oil life. Further in the presence of moisture, common by products of combustion will react chemically to produce corrosive and rust producing acids. Typically about 80% of engine wear is due to contaminants <10 microns.

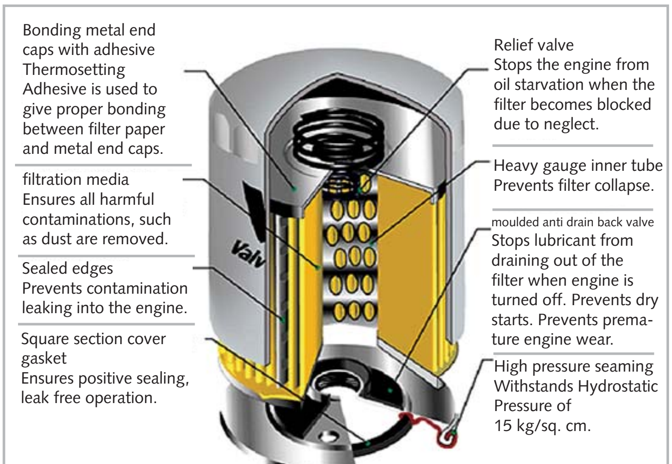


Fig. 3 Oil filter technology.

The function of oil filter is to remove soot, rust particles and other solid contaminants from the oil, providing maximum protection and safety to engine (Fig. 2). The Figure 3 shows the oil filter technology. The earliest incarnations of these filters were made from woven, mesh and paper media that caught dirt by surface phenomenon. Filters made from polyester needle felts were impregnated and is capable of trapping contamination inside its structure.

In an important development nanofiber oil filters are made with premium advanced synthetic media technology that results in fibers that have a controlled size, shape and smaller fiber diameter. The controlled media manufacturing process, low density, greater surface area, and tight pore size allows nanofiber oil filters to deliver both higher dirt holding capacity at the same pressure differential and higher efficiency compared to conventional cellulose filters.

Cellulose fibers are inconsistent in size and shape, allowing more contaminants to pass through, resulting in higher restriction and lower capacity. The synthetic media also has better durability with usage. Throughout the service life of a cellulose filter, hot oil will degrade the resins that bind the media. The synthetic media technology uses a wire screen backing pleated with the media, resulting in superior strength. Nanofiber oil filters offer extended service intervals, greater engine protection to prolong engine and equipment life, improved lubricant flow, improved cold start performance and lower operating costs.

Fuel filters

Fuel is volatile petroleum liquid that is used to power the engine. The fuel that enters the engine must first pass through the fuel filter (Fig.4), which is essential in helping to protect fuel system components such as plug fuel injectors, carburetors etc from contaminants that may be present in the fuel . When an engine receives less contamination it exhibits higher power, greater fuel economy, and lower emissions. Contaminations can originate from dirty and rusty service station storage tanks and, as the vehicle ages, from corrosion with in the fuel system components. The figure 5 shows the fuel filter technology.

Fig.4 Different type of fuel filters.

Water, fungus, bacteria, wax, asphaltite, sediment and other solids are the major contaminations present in the fuel. Water is the greatest concern because it is the most common form of contaminant. This is likely to be introduced into the fuel supply during fueling when warm; moisture laden air condenses on the cold metal walls of fuel storage tanks or from poor housekeeping practices. The effects of water in fuel can be serious. Water can cause a tip to blow off an injector, or reduce the lubricity of the fuel, which can cause seizure of close tolerance assemblies such as plungers. Further the microorganisms (also called humbugs) live in water and feed on the hydrocarbons found in fuel, which cause plugging of a fuel filter through multiplying colonies spreading throughout a fuel system.

The fuel filter will have a slime coating over the surface of the media, dramatically reducing the service life of the filter. Bacteria may be any color, but is usually black, green or brown. Draining the system will reduce microbial activity, but will not eliminate it. The only way to eliminate microbial growth once it has started is to clean and treat the system with a biocide. Wax while desirable as a source of energy in fuel, but its control in cold weather operation is needed. Wax crystals form as a result of cold temperature precipitation of paraffin. Temperatures below a fuel's cloud point will result in wax precipitation and filter plugging. To prevent plugged filters due to wax formation, the cloud point of fuel must be at least +12°C (+22°F) below the lowest outside temperature.

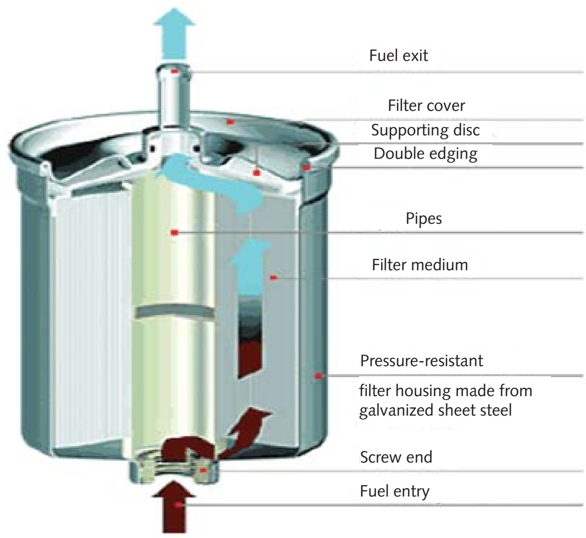


Fig.5 Fuel filter technology.

Fuel suppliers blend diesel fuel based on local anticipated cold weather conditions. Particular attention should be given to fuel purchased outside one's own area since it may not be suitable for operating conditions depending on climatic variation. asphaltite are components of asphalt that are generally insoluble and are generally present to some extent in all fuel. These black, tarry asphaltite are hard and brittle, and are made up of long molecules. Fuel with a high percentage of asphaltites will drastically shorten the life of a fuel filter. Sediment and other solids often get into fuel tanks and cause problems. Most of the sediment can be removed by settling or filtration. Fuel filters designed for specific applications will remove these harmful contaminants before they cause further system wear and damage.

The first petrol filters were made from wire mesh and, although they were efficient, they were unable to separate water from passing fuel. New filters based on vinylidene chloride polymers (namely Saran monofilament) are produced by various companies under different trade name. The filaments are made by melt spinning and are then stretched. Some of their significant properties are resistance to water, fire, light, and bacterial attack. Saran is a prime material for petrol filters and are resistant to automotive fuel, deliver high mechanical strength and recovery, flame retardant, and do not absorb water. In addition, the saran filter is able to prevent the ingress of air in to the fuel tank. The success of the filter is also due to its wicking capability. To facilitate wicking, the surface tension of the saran filter fiber is greater than the critical surface tension of the fuel. Wicking ensures that the filter is constantly seeped in fuel in the presence of air and fuel vapour. Indeed, even when the fuel tank is nearly empty, a fine film of petrol collects over the filters surface and prevents air from penetrating its structure.

Overall, the wicking function is governed by the filter medium and its construction, chiefly by the choice of fiber, finish, and pore distribution. Most saran filters are fitted in to vehicles that employ a carburator system. Here, when the engine is running, the flow of fuel is variable and intermittent. The role of the saran filter is to intercept any contamination and prevent it entering its structure or passing into the fuel tank. Particles cannot adhere to its surface as filter cloth is exceptionally smooth. Instead, the filter performs a self-cleaning operation called "back washing", where by impurities are shed from its surface when car stops.

Cabin filters

The environment will hopefully get less and less polluted, the air we breathe while driving is not always as clean as we would hope today. Another large market segment that has been dominated by nonwovens in the automotive market is the cabin air filter. An increasing number of vehicles, mainly in Europe today, are equipped with these filters, which reduce the pollution of the air penetrating into the vehicle's cabin. A few different technologies are used today in this application.

Most medias are synthetic based and often rely on finer fibres in order to stop the finest particles such as pollen and spores. Recently, more and more of these filters are combining particle filtration, whether purely mechanical or electro statically charged, with the benefits of activated carbon. These combined filters not only stop particles but also absorb a multitude of gasses and odors. New developments in the manufacturing of nonwoven media containing activated carbon, which tightly encapsulates the carbon particles, now allow manufacturers to easily pleat these media and hence design filters for awide variety of shapes and sizes.

Cabin filters are generally located under the vehicles hood, inside the glove compartment or under the dashboard and most are within easy reach for quick replacement. When the vehicle is in motion, or when the ventilation system is in use, all impurities that are present in the outside air are sucked into the cabin like a vacuum. At this point, there can be a dangerous concentration of pollutants and toxic gases. This creates a need for the filtration of the outside air, which is particularly important for the passengers in the vehicle. The use of cabin filters helps in trapping a wide range of irritating and harmful particulates, and by preventing particulate from pollen, dust, smoke and other outdoor sources from entering and contaminating the interior spaces of the vehicle.

The degree of pollution that a cabin filter encounters has a range of contributory factors including the location, atmosphere, weather and time of year. City air is most polluted, contains large doses of pollen, bacteria, aerosol, rubber, and street dust. The level of air borne pollution ranges from 0.05 - 0.5 mg/m^3 .The particles that are larger than 3 microns can be trapped in human breathing channels and responsible for instigating allergic reactions, like hay fever and asthma. In the mine area, role of cabin filter is very crucial. Air borne coal dust is a by-product of coal breakage during mining, processing and handling.

Airborne dusts can pose both respiratory and environmental problems. In mines prolonged exposure to air borne coal dust is responsible for the prevalence of coal workers pneumoconiosis. Health research studies have identified that the severity of pneumoconiosis is directly related to the amount of respirable dust exposure and the coal rank. Bureau of mines studies have identified that ignitable air borne coal dust concentration start on the order of 50 g/m^3. The most explosive coal dust size in air is below 75-micron meter. The mine safety and health administrations (MSHA'S) permissible dust standard for coal mine workers is of 2 mg/m^3 .

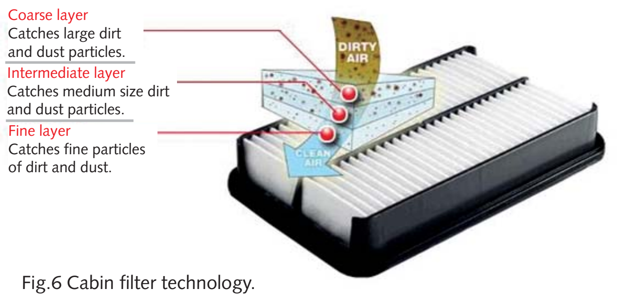


Fig.6 Cabin filter technology.

Cabin filters are available with three different designs. The particulate filter is a multilayer design composed of a pre-filter, an electrostatically charged microfiber layer and a cover layer. Each layer is made with a mold-resistant filtration media that serves to ensure maximum performance and durability. The pre-filter is made from a scaffold of coarse polyester fibers that are supported by binder. To furnish the filter with certain functional properties, the binder is formulated with a mixture of antibacterial, water repellent, and flame retardant agents. Prefilters are designed to capture larger contaminating particles, including pollen and mold spores. The electrostatically charged microfiber layers, built from meltblown polypropylene fibers attracts and holds elusive smaller-size particles from smoke, bacteria, and other contaminants. The cover layer is constructed of a nonwoven filter media that adds stability and protects the microfiber layer from damage.

It also provides an additional barrier against harmful contaminants. The activated charcoal filter has all of the features of the particulate filter, plus an activated charcoal layer that absorbs harmful gases and their odors. Activated carbon removes odor in a variety of ways, namely by physical adsorption, chemical adsorption, and by catalytic reaction within its pore. Automotive cabin filters often feature a pleated design. The pleats provide greater surface area for higher filtration capacity. The combination filter or two-stage filter combines the advantages of both filter types in one filter.

During the first stage of particle filtration the small particles such as dust, pollen, soot and spores are filtered out. The air cleansing is accomplished through the sieve-effect and electrostatic attraction of the filter medium. During the second stage the toxic gases and odors are filtered out. In some applications, two-stage filtration is accomplished using the combination of a particle filter and adsorption filter in series in the fresh air intake system.

Others filters

Apart from cleaning air and fluids that circulate inside the engine, textile filter media clean the emissions created by the used fuel. These emissions include huge amounts of petrol fumes that escape from car exhausts every day. Standard fuel tank filters are manufactured from woven saran monofilament or resin impregnated, wet laid filter paper. The filter medium is combined with a carbon element that is capable of absorbing fumes. When the car moves, the fumes are captured and sent back in to the fuel tank. Like wise, a filter to capture emissions from the diesel car was invented in the mid 1980s. Diesel exhausts consist of gaseous, liquid and solid emissions. The world health organization has labeled the polar fraction of diesel particulate as carcinogenic and hence a health hazard.

Two methods are commonly employed for reducing the particulate matter from diesel engines, namely diesel oxidation catalysts that oxidizes soluble organic fraction and diesel particulate filter, constructed of special ceramic element that is extremely heat resistant. One of these materials is a porous cordierite ceramic with magnesia/alumina/silica composition. A key property of this composition is a very low coefficient of thermal expansion. Diesel particulate filter traps the particulate matter. The dominant component of trapped particulates is soot carbon, which is formed during combustion of fuel-rich mixture in the absence of adequate oxygen. Although some of the soot may be oxidized to carbon dioxide (CO_2) during the latter part of power stroke, a major portion is not oxidized as a result of slow process.

The other major component of particulate filter consists of heavy unburned hydrocarbons. Since the chemical energy of soot carbon and heavy hydrocarbon is high, only they are ignited during regeneration. Subsequently they release a great deal of heat, which, if not dissipated continuously, can result in high temperature gradients within the filter. Thermal stresses associated with such gradients must be kept below the fatigue threshold value of filter material to ensure thermal integrity over its lifetime. This is best accomplished by using a ceramic composition with ultra low thermal expansion and/or high thermal conductivity, high heat capacity and modesty high fatigue threshold value. Other approaches to improving thermal integrity include the use of fuel additives and/or catalyst to effect regeneration at lower temperature. Alternatively, more frequent regenerations can also reduce the temperature gradients and enhance thermal integrity but at the expense of fuel penalty if a burner is used for regeneration.

NanoBreeze Air Filter

The technological basis of the NanoBreeze air filter is very similar to that of self-cleaning fabric. The filter houses a fluorescent light tube, which emits UVA and blue light. This tube is then wrapped in fiber glass coated with a nano-thin film of titanium dioxide nano particles. The light photons are absorbed by the titanium dioxide, which experiences electron excitation. UVA and blue light are chosen because the photons are in the appropriate energy range to excite electrons of the titanium dioxide (i.e. greater than the band gap).

The freed (excited) electrons then react with oxygen atoms in the air, breaking their double bond and leaving them with an unpaired electron. Because of the unpaired electron, the oxygen is a powerful free radical, which attacks other molecules within the air (i.e. the harmful gases), breaking them down via oxidation-reduction reactions. The titanium dioxide only serves as a catalyst to the reaction, so it is never used up, making the filter last as long as the light tube does not burn out (life-span of a light tube is estimated to be a year).

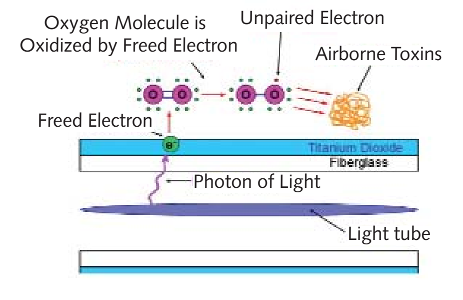


Fig 7: Working mechanism of NanoBreeze Air Filter.

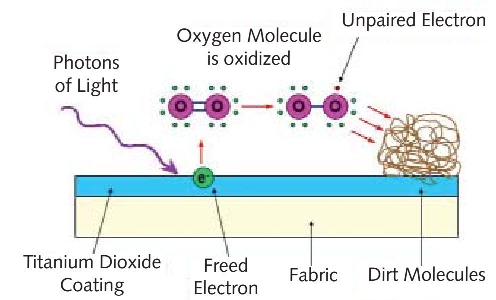


Fig 8: Working mechanism of self cleaning cloths.

How self-cleaning fabrics work?

The self-cleaning fabrics work using the photocatalytic properties of titanium dioxide, a compound used in many new nano technology solar cell applications. The fabric is coated with a thin layer of titanium dioxide particles that measure only 20 nanometers in diameter. When this semi-conductive layer is exposed to light, photons with energy equal to or greater than the band gap of the titanium dioxide excite electrons up to the conduction band. The excited electrons within the crystal structure react with oxygen atoms in the air, creating free-radical oxygen. These oxygen atoms are powerful oxidizing agents, which can break down most carbon-based compounds through oxidation-reduction reactions. In these reactions, the organic compounds (i.e. dirt, pollutants, and micro organisms) are broken down into substances such as carbon dioxide and water. Since the titanium dioxide only acts as a catalyst to the reactions, it is never used up. This allows the coating to continue breaking down stains over and over.

5. Conclusion

The performance of automotive filters is very important for effective functioning of engines as well as to maintain cabinet environment. Automotive filter business is mainly concerned with air filters, oil filters, fuel filters and cabin filters. In all the cases filters should be replaced only after a designated time period for its effective functioning. Over the past decade significant attention is being paid in designing and development of air filters, oil filters, fuel filters and cabin filters. Many new designs differing in construction and raw material has come up and continuously evolving. Presently nanofiber filter media has been successfully used in a variety of filtration applications. Nanofiber filters are appropriate for wide range of filtration applications mainly due to its low density, large surface area to mass, high pore volume and tight pore size.

References

1. Mukopadayay S K & Partridge J F, Automotive Textiles, Textile progress, 29, No.1/2, 1997.
2. Automotive filters Viju-S Mukhopadhyay-A Asian-Textile-Journal. 2006; 15(5): 49-55.
3. http://www.wixfilters.com/productinformation/gff_fuelfilters. html.
4. http://www.wixfilters.com/productinformation/gff_transmissionfilters.html.
5. http://www.wixfilters.com/productinformation/gff_coolantfilters.html.

The authors: P.Ganesan and L.Sasikala are lecturers at the Department of textile technology, PSG College of Technology, Coimbatore (India). Messers S.Sundaresan, K.Gowri, R.Senthilkumar are lecturers at the Department of Textile Technology, Kumaraguru College of Technology, Coimbatore. ◆

UFI Report: Trade fair market in Asia grows by 8.7% in 2008

The trade fair industry in Asia expanded by 8.7% in 2008 despite the weakening global economic environment according to the fifth edition of UFI's annual report on the trade fair market in Asia. Net area sold by organizers in Asia reached a total of 14.3 million square meters. The research was once again undertaken for UFI, the Global Association of the Exhibition Industry, by Business Strategies Group (BSG) in Hong Kong.

China's growth continues to outpace the rest of the region. It is the largest market in the region in terms of space sold and industry revenues. Year-on-year, net square meters sold in China grew by 14% outperforming the regional average of 8.7%. Over 7.6 million square meters were sold in China in 2008 – accounting for 53% of 14.3 million square meters sold across Asia. The second largest market, Japan, continues to lose ground to China. The Japanese market shrank by more than 6% last year with 2.0 million square meters sold.

A number of much smaller markets grew faster than China last year. Space sold in Macau expanded by 69% on the back of the opening of the new venue at the Venetian. Taiwan grew by 26% and Vietnam by 24% in terms of square meters sold which was also primarily driven by additional, new capacity in both markets.

Revenues from trade fairs in Asia increased from US$3.25 billion in 2007 to US$3.45 billion last year – an rise of just over 6%, down markedly from the 26% revenue growth recorded in 2007. China outperformed all of the top five largest markets (measured by revenues) by a wide margin posting a 20% increase in revenues for a total of US$1.33 billion.

This report provides detailed information on the development of trade fairs and supporting facilities in 15 markets: China, Hong Kong, Macau, Australia, India, Indonesia, Japan, South Korea, Malaysia, Pakistan, Philippines, Singapore, Taiwan, Thailand and Vietnam. The report also includes analysis on actual market performance in 2008 as well as forecasts and commentary on key trends in each market.

Vincent Gérard, UFI Managing Director, commented, "2008 was another noteworthy year for the exhibition industry in Asia. Despite a challenging economic environment, space sales in the region as a whole grew by close to 9%. Seven different markets posted double digit growth – and of those four grew by more than 20%."

As an added-value service, each UFI member will be entitled to receive a six page executive summary of the research and to purchase the full report at a substantial discount.

The report has again been edited by UFI Asia/Pacific Regional Manager and BSG Principal, Paul Woodward. He commented, "Asia continues to be one of the most vital and exciting exhibition markets in the world. Despite the global economic recession, in 2009 BSG is still forecasting growth in several of the region's key exhibition markets including China and India. The pace of change here has been nothing short of remarkable. In 2003, there were 101 venues in the region and space sales were just 5.7 million square meters. By the end of this year, Asia will be home to 162 venues generating space sales of 14.6 million square meters."◆